SYNOPSIS

Synthesis and Characterization of Photoconductive Semiconducting Thin Film on Flexible Substrate for Application in Flexible Electronic Devices

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Title:

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1. Introduction:

The development of semiconductor thin films for flexible electronic devices has covered a wide range of applications including photodetectors, displays, solar cells, optical logic gates, light-emitting diodes (LEDs), optical-image sensors, etc [1,2]. In case of thin film, due to its thickness confinement strong interlayer quantum confinement effect contributes to the extraordinary optoelectronic performance of the corresponding fabricated devices. Moreover, their thin nature and strong in plane covalent bonding makes it inherently flexible. This characteristic makes it highly suitable, as active channel materials, for applications in mechanically flexible electronics and optoelectronics [3,4] devices.

Among all semiconductor materials, metal oxides/sulfide plays very important role in chemistry, physics and materials science. As the metal elements can form a large diversity of oxide/sulfides compounds and can acquire various structural geometries (1D / 2D / 3D). Metal oxide/sulfides can show unique electronic properties depending on its shape, size and doping concentration. In technological applications, metal oxide/sulfides thin films with thickness ranging from several nanometers up to several micrometers are utilized in the fabrication of microelectronic circuits, sensors, piezoelectric devices, fuel cells, coatings for the passivation of surfaces against corrosion, catalysts, etc.

Synthesis of thin film metal oxide/sulfides nanostructure material has beedn demonstrated via different techniques included in Wet Chemical, Physical Vapour Deposition (PVD) and Chemical Vapour Deposition (CVD) techniques. Each methodology has associated with its pros and cons, and careful consideration of the resulting film properties such as crystallinity, microstructure and adhesion must be taken into account before its viable use in device technology.

2. Review of Literature and Development in the Subject:

Recent literature survey show large number of research reports in the field of metal oxide/sulfides thin film fabricated on hard substrates for application including solar cells, thin film transistors, sensors, resistive switching devices, ferroelectric memories, etc. These films are prepared extensively by physical vapour deposition techniques like Pulsed laser deposition, Atomic layer deposition, Chemical vapour deposition, Sputtering, etc. Whereas, the use of spray pyrolysis technique is just limited to synthesis of thin film materials required for solar cells, sensors, catalysis, photodetector, etc. Few

reports are available to fabricate metal oxide/sulfide thin films or nanostructures on flexible substrates, as

Wei Zheng et al [5] reported an ultrafast-temporally-responsive flexible photodetector with high sensitivity based on high-crystallinity organic–inorganic perovskite nanoflake.

Daniel Schneider, et.al. [6] report on highly responsive flexible few-layer MoS2 photodetectors based on MoS2 synthesized uniformly for full coverage of 2 inch sapphire wafers using metalorganic vapor-phase epitaxy.

Yourong Tao, et.al [7] in this study reported flexible photodetector from ultraviolet to near infrared based on a SnS2 nanosheet microsphere film. In this article they have developed two novel, either fexible or rigid, SnS2 nanosheet microsphere film photodetectors with a good photoresponse in the region of UV (300 nm) to NIR (830 nm) light. The results show that both devices possess a high spectral selectivity, good photoresponse, and good stability.

Wei Hu, et.al [8] in this study they reported High-Performance Flexible Photodetectors based on High Quality Perovskite Thin Films by a Vapor–Solution Method. In this work they find that a high-quality perovskite thin films on flexible PET substrates have been grown using a developed vapor–solution method. Structurally homogeneous PbI2 layers were first prepared using a novel vapor deposition process and then converted into high-quality perovskite thin films through a fast nucleation and crystallization process. Based on the as-prepared perovskite thin films,

Tao Dong, et.al [9] in this study reported flexible Photodetector Based on 2D Materials: Processing, Architectures, and Applications. In this work, they display that 2D material flexible photodetectors have some interesting applications in UV imaging. Aiming to test this application Ali et al. developed a graphene/silicon metal–semiconductor– metal (MSM) UV photodetector on a PI substrate.

Sohail Abbasa, et.al. [10] in this study reported all metal oxide-based transparent and flexible photodetector. In this work, they demonstrated the fabrication and characterization of flexible and transparent photodetector based on conformally grown AgxO/TiO2/ITO layers on polyethylene terephthalate substrate. Initially, the thickness of AgxO and ITO layers were optimized via deposition time to match layers crystallinity with fixed intermediate TiO2 layer, for better optical and electrical properties. The highly transparent (> 70%) and flexible device presents the high-preforming responses over the broadband light. Under UV illumination, it showed a high responsivity (323 mA/W) and detectivity (4.2×10^8 Jones).

Qiao, Hui, et.al [11] presented a comprehensive summary of the latest research progress of 2D material-based self-powered photodetectors .In addition, we also discussed in depth the self driving mechanism of three self-powered photodetectors and the effect of 2D material structure on device performance .Therefore, 2D material-based

self-powered photodetectors have been extensively studied for their excellent optical response performance and have become an important part of self-powered photodetector.

3. Objectives of Research/proposed Hypothesis

This work investigates the photoconducting properties of metal oxide/sulfide thin films synthesized using spin coating / spray pyrolysis technique on flexible substrates and possible development of highly sensitive and responsive optoelectronic device using the deposited film.

To achieve the above mention objective this work is made of specific aims;

a. To synthesize metal oxide (MO_x) or metal sulfide (MS_x) thin film (pure or doped) on polymer substrate using spin coating / spray pyrolysis technique.
b. Characterize these thin films using XRD, UV–Vis spectroscopy, Raman spectroscopy, TGA-DTA, SEM-EDS, XPS, etc.
c. To investigate the photoconducting properties of MO_x / MS_x thin film samples using dedicated optoelectronic characterization setup. This includes responsivity, detectivity, response (rise/decay) time, sensitivity, gain, etc.
d. To investigate the electronic structure of the film using X-ray photoelectron spectroscopy and understanding the role of its intrinsic properties on charge transport
e. To propose effective photodetector device based on the results and material properties.

4. Methodology to be adopted

This work includes synthesis of MO_x / MS_x materials (pure or doped) for its viable application in development of optoelectronic device application. This work designed to run on three stages;

Stage-1: Fabrication of thin films of metal oxide/sulfide:

The motivation behind this stage is to investigate the growth and physical properties of amorphous and polycrystalline metal oxide/sulfide films grown on polymer substrate. Individual goals of this stage are

a. Synthesis of high quality MO_x / MS_x thin film (pure or doped) on polymer substrate via spin coating or spray pyrolysis technique.
b. Characterization of the thin film using XRD, TGA, UV-Vis spectroscopy, Photoluminescence spectroscopy, SEM and AFM.
c. Investigation of photoconducting properties of MO_x / MS_x thin film with respect to their thickness, dopant concentration, electrode gap.

Stage 2: Establish the electronic structure of the films and correlate with its photoconducting property:

a. Investigation of the electronic structure of the MO_x / MS_x thin film (pure or doped) using X-ray photoelectron spectroscopy.
b. Correlating the role of deposition parameters, dopant concentration and film thickness with the observed photoconducting properties.

Stage 3: Development of flexible optoelectronic device based on the obtained results:

The flexible substrate used in this work must be optically inert.

a. Investigation of photoconducting properties of MO_x / MS_x thin film on various flexible substrate.
b. Use of the above investigated properties of the dopant for determination of viable optoelectronic material based on MO_x / MS_x thin film.

During the final stage of the work, efforts will be made to fabricate and demonstrate MO_x / MS_x thin film based optoelectronic device for its viable application in current semiconductor market.

5. Importance of study/ Society application:

National status:

A number of important research outcomes addressing a variety of issues in this field are supported and many are in progress in various National laboratories and universities in the country funded by Government of India. Although it is difficult to summarize the whole effort, a representative cross section of ideas and strategies can be provided as follows: Dr. S. B. Ogale, Dr. Suhas Jejurikar, Dr. Indrani Banerjee, Dr. Abhimanyu Rana, Dr. Rajesh Hyam, Dr. S. S. Islam, Dr. S. H. Husale, etc.

International status:

Continuous advancement in the flexible device technologies over the past decades has given us devices with powerful capabilities due to advance materials. Many researchers across the globe are working to enhance the performance of flexible PDs. In the specific research area to be focused upon in this work, the international research is just beginning to grow creating an open opportunities for Indian science to take a lead and make a substantial impact. These developments are occurring in the domains of new device concepts. Few impressive examples who flourish the focus of this project are: Dr. Joondong Kim, Dr. S. Sawyer, Dr. Guowei Yang, Dr. U. Jeong, Dr. Z. L. Wang, Dr. Y. A. Zhang, Dr. H. J. Kim, etc. Lots of literature is available on various reputed research

journals like: Nature, Science, Advanced Materials, Nano Letters, Advanced Functional Materials, etc.

Significance of the study

In recent years, extensive research is going on in the area of synthesis of highly functional material owing to its promising applications in the field of opto or nano-electronic devices. Recent reports has shown MO_x / MS_x thin film based light-emitting diodes, photo-detectors, solar cells, thin film transistors, etc. These thin films have been synthesized via various physical and chemical methods, including vacuum evaporation, sputtering, electro deposition, molecular beam epitaxy, photochemical deposition, spray pyrolysis, metal organic chemical vapour deposition, chemical bath deposition, screen printing and sol-gel assisted spin coating method. Among these techniques, the spin coating or spray pyrolysis method are relatively simple and gives higher coating area, high superior homogeneity, high purity, better micro structural control and narrow thickness variation as compared with those prepared by physical methods. The spin coating or spray pyrolysis method have additional advantages like its simplicity, cost effectiveness and its ability to deposit uniform films, moreover, its reproducibility in a relatively shorter processing time at lower temperatures is remarkable. Current electronic industries need a method, which is low-cost, and large-scale integration.

It is appealing to state here that the MO_x / MS_x thin film based flexible substrate are significantly promising candidates for high performance photodetectors because of their high photoresponsivity and mechanical properties. The commercially available photodetector do have limited mechanical stability and is due to the mechanical mismatch between their two-dimensional channel materials and metallic contacts. Herein, we propose to develop a type of mechanically stable, highly responsive, and flexible photodetector by integrating MO_x / MS_x thin films structures on flexible substrates. These make our proposed photodetector a promising candidate for flexible photodetection applications.

6. Proposed work Plan/ Formulation and Structure of Study: Year-wise Plan of work and targets to be achieved

First year:

a. Initiate synthesis of pure MO_x / MS_x thin film (TiO_2, ZnO , CdS, PbS, etc.) on flexible substrate.
b. Initiate and optimize thin film growth methods (spin coating / spray pyrolysis) for synthesis of functional MO_x / MS_x thin film.
c. Study the effect of temperature and substrate on film morphology.

d. Perform extensive characterization including UV-Vis, XRD, AFM, TGA, SEM-EDS and XPS to study the structural, morphological, optical and electronic properties of synthesized thin film.
e. Initiate testing of photoconducting properties of pure MO_x / MS_x thin film.

Second year:

a. Initiate and optimize deposition technique for synthesis of functional MO_x / MS_x thin film on various flexible substrate.
b. Initiate and optimize thin film growth methods (spin coating / spray pyrolysis).
c. Study effect of thickness and temperature on film morphology.
d. Perform extensive characterizations including UV-Vis, XRD, AFM, TGA, SEM–EDS and XPS to know the structural, morphological, optical and electronic properties of MO_x / MS_x thin film.
e. Test of flexible device properties of MO_x / MS_x thin film.
f. Start publishing research papers

Third year:

a. Review the status of progress during the first two years and take appropriate steps towards the most effective utilization of the knowledge, facilities and experience during the remaining duration **.**
b. Continue to analyze the data obtained and proceed with publications / petenting as appropriate.
c. Prepare thesis for submission**.**

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